[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Notes On the Northern Black Hills of South Dakota.

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(Chicago Meeting, February, 1897.)

General Geology of the Northern Black Hills.

The "Black Hills of Dakota," to the northern part of which the following observations apply, occupy a position on either side of the boundary between Wyoming and South Dakota, approximately between 103° 15′ and 104° 48′ of west longitude and 43° 15′ to 43° 50′ of north latitude. The area is roughly 4160 square miles.* (See Plate I.)

As has been pointed out by Profs. H. O. Hofman, F. W. Carpenter and others, and illustrated by Mr. Newton in the publications of the United States Geological Survey, these hills are made up of a large number of the known formations from the Archean to the Tertiary, which latter constitutes the border of the region. The mining operations are largely confined to the interior of this area, and the centers from which they are conducted (Deadwood, Lead City, Galena, etc.) are situated near the line of junction of the Archean schists and quartzite, supposed to represent the Potsdam Sandstone of the N. Y. series, or the lowest of the Paleozoic measures.

The Archean or pre-Paleozoic rocks consist mainly of a mica-schist in which hornblende and garnet are frequently

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* There are many of my fellow-members to whom the aspect of the Black Hills and the adjacent Bad Lands is familiar—in the more genial months of late spring, summer, and early fall; but to these, even, the conditions surrounding this lately re-exploited country in the middle of winter are unknown. Very lately it became necessary for me to undertake a visit of exploration to the Deadwood district while the thermometer was registering —42° Fahrenheit, and the high winds prevailing in early December of 1896 were creating havoc with those settlers who were imprudent enough to brave the elements without sufficient protection, or who had not adequately housed their stock.

By singular good luck the blizzard and I crossed each other *en route*, and I found in Northern South Dakota one of the most delightful winter-temperatures I have ever known.

found, but which varies in texture and composition so as to resemble not infrequently the hydro-mica schists or "nacrites" of the late Dr. T. Sterry Hunt, and again to assume the appearance, and in part the constitution, of heavy bedded gneiss. These schists are upturned at high, often vertical angles, while over them unconformably, and dipping gently towards the horizon is the quartzite in its various forms; sometimes apparently undisturbed, and at others broken or "brecciated," as it is often called (*i.e.*, shattered into angular fragments and recemented without very great displacement of the parts) by the numerous porphyry dikes which intersect all the exposed measures from the lowest to the highest, and form a part of the elevations or hills of the region. These latter are without question eruptive, and bear evidence of having been ejected during at least two and probably several different epochs, for I have observed porphyry in places intersecting older masses of similar porphyry, which, in their turn, have produced earlier disturbances in the strata.

The same paper contains a geological section taken from the equally admirable and earlier contribution of Walter B. Devereux, on "The Occurrence of Gold in the Potsdam Formation, Black Hills, Dakota" (*Trans.*, x. 465).

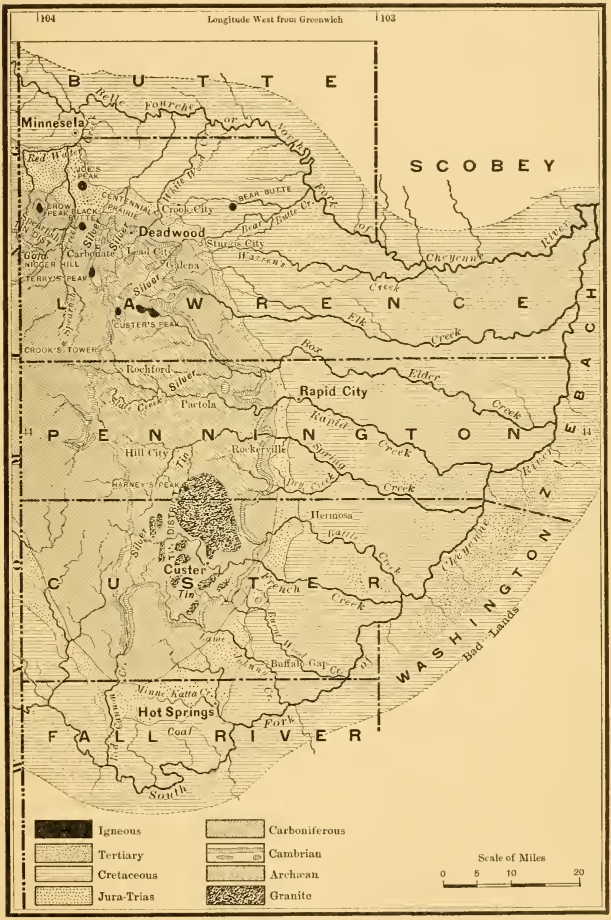
The first systematic study of this region was made by Dr. F. V. Hayden, in 1870, and resulted in the geological definition of the large divisions of the Hills much as they are accepted to-day.

Since then the Government has had the very full report on the geology and resources of the Black Hills by Henry Newton and W. P. Jenney, 1875 (Report published in 1880). Still later Devereux, Blake, Headden, Hofman, Carpenter, Rickard, Farrish, Dr. McGillicuddy and others have published valuable contributions to our knowledge of the geology, mineral resources and chemical character of the ores of the Black Hills, which will be referred to more specifically in their proper places. Plate I., accompanying this paper, is a reproduction in black and white of the geological map published with the admirable paper of Prof. F. B. Carpenter (*Trans.*, xvii., 598) on "The Ore-Deposits of the Black Hills."

The district which is my present subject, lies in that part of the northern Black Hills immediately around Galena and three

miles west and three miles southwest of that camp, which is some six miles southeast of Deadwood in an air-line.

PLATE I.



Geological Map of the

BLACK HILLS OF DAKOTA

After the Map of Henry Newton, E.M.

By Franklin R. Carpenter, Ph.D.

According to the topographical sheet of the United States Geological Survey (Deadwood, S. D., Ed. of Feb., 1894), the town of Galena lies on the 4800-foot contour-curve above tide. The hills along Bear Butte creek rise to 5200 and 5300 feet, making their summits 400 to 500 feet above the creek. To the northwest, or between Galena and Deadwood, and to the southwest, near the intersection of Bear Butte and Strawberry gulches, the extreme summits reach 5500 feet.

The numerous gulches follow many directions; but those which predominate are approximately northeast-southwest and northwest-southeast. The valleys are generally deep and the hillsides steep, indicating a considerable erosive action of the streams on the sides, and accounting for the numerous placer-deposits found in their beds.

The geology of the region, if not simple, is at least not complicated by a large number of formations.

The mica-schists, thought to be upper members of the Archean, are found at the lowest levels along the streams and higher up on the hills, as at the Cora mine, striking northeast-southwest, and dipping at angles from 38° to 85°.

These schists are generally micaceous and coarse-grained and usually rather reddish from the dissemination among them of iron oxides; but they vary greatly, sometimes passing into the type known as nacrite or hydro-mica schist (which here also has been frequently but incorrectly taken for talc schist) and sometimes, though more rarely, assuming a heavy bedded character reminding one of gneiss.

They are most frequently crumpled and conchoidal both in small and in large bed planes.

Explorers.—Hayden reported the Black Hills of Dakota as one of the plainest and most interesting exhibits of the series from the granite upwards, of all localities known in the West.*

Newton and Jenney issued a most instructive volume,† and one which has served as a mine for all future observers. The map accompanying this work is that generally used for all purposes of geological illustration of the region to-day.

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* Meek and Hayden: "Some Remarks on the Geology of the Black Hills and Portions of the Surrounding Country," *Proc. Acad. Nat. Sci.*, *Phila.*, vol. x., pp. 41–49, 1859.

† "Geology of the Black Hills and Mineral Resources of the Black Hills of Dakota," *U. S. Geol. Survey*, 1880.

Walter B. Devereux* thought that the oldest visible formations near Deadwood were palæozoic schists (?)

Resting unconformably upon them was a sedimentary formation composed of débris derived from them, *i.e.*, the Potsdam. The lowest is a conglomerate. The mines in the lower part of the quartzite are called cement-mines. The deposits were found on the east side of the Homestake vein. Only one deposit was worked on the western side.

The mass of the conglomerates was a mixture of quartz boulders, pebbles and schist, with pebbles of hematite; gold was present as a mechanical, and in the cement-beds as a chemical, constituent. In general only 5 or 6 feet of rock will pay for mining or milling. Cutting through a dike, he found that gold was seldom present in close proximity to the porphyry. Gold plates are found along the interior plane of the "talc" (?) schist. The schists underlying this deposit were found to contain gold for about 10 feet. The ores of Bald mountain seem to be impregnations.

1. The metallic constituents were segregated along certain horizontal strata. 2. There was concentration along certain vertical planes which were contacts of quartzite with porphyry dikes. The dikes themselves were found to be lines of mineral segregation below the contact of quartzite and of the schist. He inclined to the belief that the gold came partly from below and partly from the concentrated sediments above.

In one place the sedimentary stratum gave $20 per ton in gold, though so fine that no gold could be panned.

Argentiferous lead-ores have been mined from the quartzite. These mineralizations probably are of the age of the porphyry.

Dr. Headden† thought that the strike of the granites was the same as the schists with which they are interstratified. The granites further north are more varied. It is a question whether they are continuous undeground. On the eastern margin of the schists occur lenses, some large and some small, with their longer axes parallel. Many of the granites are intrusive. There is no porphyry in the southern section of the Hills.

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* *Op. cit.*, *Trans.*, x., 465, May, 1881.

† "Notes on the Hist., etc., of the Black Hills," by Dr. W. P. Headden, *Proc. Colo. Sc. Soc.*, vol. iii., pt. 3, p. 347.

The Cambrian is unconformable on the schists, part of which form its basal conglomerate.

Prof. Hofman* says that the gold is found in quartzite and pyrite finely divided through mica- and amphibole-schists, and impregnates the schists. Its associated minerals are pyrite, with some arsenopyrite, chalcopyrite, garnet, and asbestos. The ores from the upper cuts and levels are more free-milling than those below the water-line. The assay-value of pure concentrates is $4 to $90 per ton; the average perhaps $25 per ton. The porphyry forms barren horses.

From the valuable contribution to this subject made by Prof. Carpenter† I have compiled the following summary:

The Cambrian is represented only by the Potsdam and rests unconformably on the Archean schists. No Silurian or Devonian is found, and the Potsdam and Carboniferous are conformable. The great deposits are of Archean age and yield mainly auriferous pyrite. There are sometimes lenticular and seemingly independent masses of the slate and schist series sharing the folds and contortions and having a columnar cleavage coincident with the bedding. The porphyry flowed over the Potsdam east of Deadwood and under that in the Homestake to the west, lifting it like a laccolite. The gold was deposited by chemical action after having been segregated.

The smaller the particles the finer the gold (Devereux).

Assays of Homestake porphyry show that it contains no gold. The whole thickness of the beds in which these ore-bodies occur is about 2000 feet.

The ore-bearing rocks are co-extensive with the igneous rocks.

The Potsdam ores occur at different levels, especially in the upper parts of the lower quartzite. Bluish quartzite contains very finely divided pyrite in a siliceous paste, which unites the rounded grains of silica. The solutions which brought this material to fill the spaces between the grains brought also the silver and gold. At Galena the proportion of gold is greater in the lower contact, while silver predominates in the upper, which are the more calcareous parts of the Potsdam. In the limestone the deposits carry lead and silver; but the porphyry is the same. The solutions followed certain bed-planes which are on the quartzite and in the lime-shales of the Potsdam. The connection between the overlying porphyry and the ore is intimate. Where one is wanting, so also is the other. The crystalline schists below have nearly always shown gold. Perhaps the porphyry only induced hot waters which dissolved and redistributed it. The slates below the Potsdam at Galena show galenite also (in the Oro Fino mine). Blende, galenite and pyrite occur in the porphyry.

At Galena there are three distinct "contacts" or levels of ore, always on quartzite, on which it is found replacing parts of the thin lime shales, and over it, though not always in contact, is porphyry.

No ore-bodies have been found to pass from the porphyry into the Archean.

* "Gold-Milling in the Black Hills," by H. O. Hofman, *Trans.*, xvii., 498, Feb., 1889.

† *Op. cit.*, *Trans.*, xvii., 570, Feb., 1889.

The outcrop of the Galena deposits is almost always lead and iron carbonates carrying silver. The depth at which these become sulphides varies with the position of the deposit; in the lower contact, quickly; in upper contacts, they continue to greater depth.

The "veins of granite" of Newton, Jenney, Blake, and Vincent are segregated parallel to the apparent bedding. They are lens-shaped and succeed each other in strike, and probably also in dip. They are tabular in form (?) When tin is present, one of the constituents of the granite Is wanting, and the rock becomes quartz and mica, or quartz, feldspar and mica.

The quartzite which is the main locus of the ores lies unconformably upon these schists, not deviating more than 20°, but usually presenting the appearance of being in general nearly horizontal. This quartzite is sometimes banded, and so compact as scarcely to differ from a quartz-vein aspect; but usually it is of comparatively uniform light color, interspersed here and there with small crystals of pyrite and arsenopyrite, and, in the region under discussion, much broken from the intrusion of numerous dikes of porphyry.

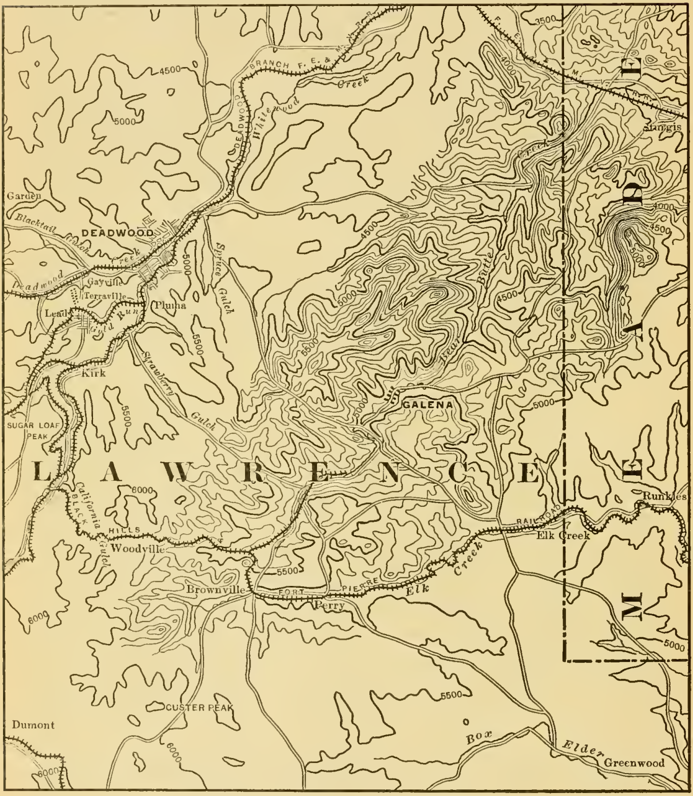
Galena, zincblende, arsenopyrite and other accessory minerals are found on the fracture-planes of the quartzite, and to a certain extent within its mass near to these planes. There are three levels of the quartzite rock in what has been taken for the Potsdam formation, and there is evidence of quartzite horizons.

In general it may be said that the alteration of the original sandstone to quartzite is more complete in the lower than in the higher horizons, and that the highest of these siliceous members of the Potsdam is capped by a series of shales or "lime-shales."

The topography of the Galena region has already been stated in general terms. (See Plate II.) It consists of a network of narrow and deep gulches separated by steep hills whose shoulders are about 300 feet, and whose crests are 500 feet above water-level. It is more than probable that the directions of these narrow valleys in many instances indicate the directions of porphyry outflows between the broken quartzite and shale, since the decomposed porphyry is the most easily eroded of all the rocks in the region, and would offer the least resistance to the wearing action of running water. Still, other causes were potent in modeling the hills as we now see them, among which a very important one must have been the agency of moving ice. However this may be, the steep portions of the hills up to the shoulders just spoken of are largely composed of quartzite. The summits, in those localities where the porphyry has overflowed, show by their gentle slopes the characteristic moulding of weathered porphyry; but in other localities a different contour is noticeable, characteristic of the almost equally soft "lime shales." It is important to keep in mind this general distribution of the porphyry, and especially so when considering the Union Hill mining properties (See Plate III.),

because the Hill is largely composed of porphyry, and, from the state of the gold which it contains, constitutes a valuable ore. The earlier geologists who examined the Black Hills were

PLATE II.



GALENA DISTRICT, SOUTH DAKOTA.

(Reduced from Deadwood Sheet U.S.G.S.)

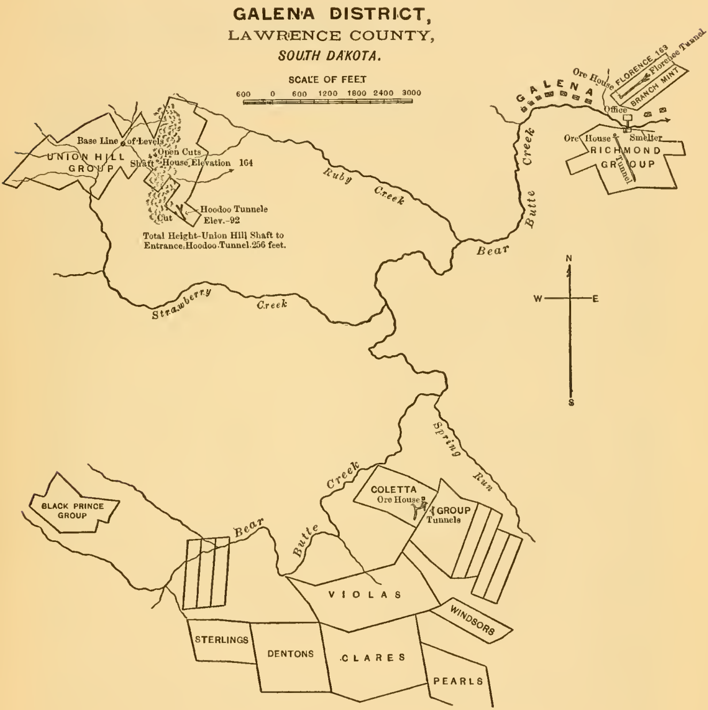
Scale of Miles

1 0 1 2 3 4 5

of the opinion that this rock was barren of valuable metals. Thus Devereux reported that about 5 or 6 feet of the quartzite would pay for mining and milling, and that "gold was seldom

present in close proximity to the porphyry." He thought that the planes of contact, fracture and bedding were enriched, and that 10 feet or so of the schists below the quartzite (the schists underlying the Potsdam) contained gold. The Bald mountain

Plate III.



deposit he regarded as an impregnation. Carpenter believed that the Homestake porphyry contained no gold, but that the thickness of the beds in which ore-bodies occur was 2000 feet, and that the *ore-bearing* rocks were co-extensive with the igneous rocks. He was of the opinion also that the solutions which brought the finely-divided pyrites to fill the spaces between the grains, brought silver and gold; that the connection

with the porphyry was intimate in the Galena region; but that, perhaps, the porphyry only induced the hot waters which dissolved and redistributed the gold.

Blende, galenite and pyrite, he says, occur also in the porphyry, *but no ore-bodies have been found to pass from the porphyry into the Archean.*

Prof. Hofman mentions the quartzite and schists as carriers of gold, but describes the porphyry as forming "barren horses."

Nevertheless, subsequent tests of at least a part of the porphyry outflows show that, to some extent, free-milling gold is carried in this rock, and on account of its enormous extent and the ease and economy with which it can be mined, it is important to determine its richer zones. To this end a number of openings have been made on the surface of Union Hill. A shaft nearly 300 feet deep to the bottom of the sump has been sunk, and a tunnel of 359 feet N.W. from mouth to heading has been run, with a cross-cut 123 feet E. of N., begun from a point 227 feet from the mouth of the main tunnel.

Starting at a cabin stable on Strawberry creek, near Mr. Fagan's house, I ascended the hill in an easterly direction, taking carefully-averaged samples from a pit at the base of the hill. The material is a weathered porphyry and the pit about 10 feet deep (nearly filled with snow at the time of my visit). Between this pit and the open cut, about 150 feet N.E. and considerably higher, nothing was observed on the surface but porphyry in various stages of decomposition. The rock in which it is excavated is also a rotten porphyry, of which large masses are exposed. In this cut a small natural bridge of rock has been left standing.

About 50 feet west of this cut is another, also in decayed porphyry, in which the principle cleavage-planes dip more or less westerly. Both the last-mentioned openings are near the shaft-house at the top of the hill.

The shaft-house covers a shaft 280 feet deep, with a sump of about 20 feet below the second level. At the time of my visit the lower level was inaccessible, and I visited only the first, or 140-foot, level, from which two drifts had been started, one extending 30 feet S.E. and the other 40 feet N.W. of the shaft.

At the breast of the S.E. drift a "horse" of "barren quartzitic

rock" had come in at the roof, inclining E. about 45°, and apparently of lenticular shape.

The porphyry in the N.W. drift is remarkable for being very full of disseminated pyrite. It is said to be the only instance of the kind thus far found in the Union Hill shaft.

In a cut near the shaft-house a loose mass of quartzite was observed, lying in porphyry.

Renewing the examination of the surface of the hill from the top of the shaft, I visited a cut in white porphyry about 700 feet east by south of the latter and obtained samples for analysis. An experimental shaft in porphyry, about 200 feet S. 10° E. of the last and 180 feet lower, also furnished samples which were analyzed. A winding open cut in rock, similar to that which has been above described, about 50 feet long, about 250 feet south of the last point, and said to be about 50 feet above the floor of the main Hoodoo tunnel, was examined and sampled. Finally, a short tunnel in rotten porphyry, with apparently horizontal cleavage-planes, about 150 feet W. 20° N. of the mouth of the main Hoodoo tunnel, yielded its quota to the material collected for investigation.

About 150 feet E. 20° S. from this cut is the mouth of the Hoodoo tunnel proper. The opening of this tunnel is in porphyry like that of the other openings described, but with planes of cleavage (thought by some to correspond to the stratification of the disturbed quartzite), dipping SE. 20°. These planes are also noticeable in the upper and shorter tunnel.

This rotten porphyry extends inward for about 60 feet, where it is replaced by a broken quartzite mixed with fragments of slaty material. This character is maintained for another 64 feet (or to a point 124 feet from the mouth) where a heavy-bedded flaggy slate is met on the hanging-wall, dipping 40°—S. 35° W. No porphyry, however, is visible. On the foot-wall is the "brecciated" slate, with fragments of quartz, some of it banded. Between this and the spot just referred to were two places some 50 feet apart, where brecciated slates and quartz formed the principal part of the rock. At the heading of the Hoodoo tunnel, 359 feet from the mouth, occurs a fragmental quartzite following more or less the plane of bedding of the slates. According to report, the quartzite mass here is about 40 feet below the lower surface of the por-

phyry outflow. This under surface must, therefore, cut the tunnel at 60 feet from its mouth, and its slope would be 1 foot in 7 or 8 to the south.

The upper Hoodoo tunnel is about 15 feet higher in level than the main tunnel, and is all in porphyry. If this be the main body of porphyry and possess an even under-surface, it would make the slope more nearly 1 in 2, and imply a dip of 30° from the mouth of this tunnel to the intersection of the porphyry and the main tunnel.

In the cross-cut from its junction with the main drift for 63 feet, the rock is fragmental quartzite interspersed with schists and shales; but at this point the porphyry appears and continues to the heading.

Assuming the floor of the upper tunnel to be fifteen feet higher than that of the main tunnel and the distance 150 feet to the intersection of the porphyry and the cross-cut, the fall of the latter would be 1 in 10, corresponding to an angle of about 60°. If these two bodies of porphyry are connected, as is practically certain, the facts would indicate that the strike of this sheet of porphyry is N.W. and S.E., and that the hill west of Strawberry creek and the Union Hill proper are on the same porphyry dike.

This hill is distant from the shaft-mouth about quarter of a mile, on the west side of Strawberry gulch. The surface of the hill shows the same decomposed porphyry as Union Hill, above described, and the shallow openings, wherever made, bear out these indications; but it is not certain how thick this cap of porphyry may be. On the summit of the hill and about quarter of a mile in a direct line from the Union Hill shaft is a cut in decomposed porphyry 30 feet long, 17 feet deep and 2½ feet wide, in the bottom of which a nearly vertical vein widens to 2 feet from 8 inches at the surface. Small crystals of galenite are said to have been found in this vein. It is also reported that galenite has been taken from a dark ferruginous gangue.

Near by is a shaft 126 feet deep. At the deepest point, an iron-ore is said to have been found, of which specimens were seen on the dump-pile. On both sides of the shaft appears a vein, which, at the depth of 100 feet, is said to have been 5 feet wide.

A very instructive and interesting phenomenon, of a dike of

porphyry cutting porphyry, was observed near the cut on top of this hill. It has a nearly vertical dip and a strike of N. 35 W.

If this observation be correct, it proves that there were successive outflows of porphyry at different epochs, and it may well be that one of these (not improbably the later) was more barren of the precious metals than the original outflow. At least a difference in age would confirm the hypothesis that there are different kinds of dikes in this region, some of them auriferous and some of them entirely barren. One of the latter is seen on top of the hill near the Cora mine, S.W. of Galena.

The assays of the specimens taken were as follows:

No.	Description.	Dollars per Ton. Gold.	Dollars per Ton. Silver.	Total Dollars per Ton.
1	Surface of Union Hill	0.4134	....	0.4134
2	" "	0.8268	0.096	0.9228
3	" "	0.4134	0.096	0.5094
4	Average ore, experimental pit, 700 feet E. by S. of U. H. shaft	Traces.	....	....
5	Do., experimental pit S. of U. H. shaft	....	....	....
6	Do., deep cut, 165 feet N.W. of mouth of Hoodoo tunnel	11.57	0.228	11.7980
7	Do., deep cut	3.7206	0.480	4.2006
8	Shaft, Union Hill, "Horse," first level, heading S.E. drift	0.4134	....	0.4134
9	Do., first level, heading S.E. drift	0.4134	0.096	0.5094
10	Do., first level, heading N.W. drift	0.4134	0.072	0.4854
11	Upper Hoodoo tunnel	0.4134	0.070	0.4554
12	Main Hoodoo tunnel	3.5139	0.192	3.7059
	Total gold and silver in 12 tons of samples.	....	....	$23.41
	Average per ton	....	....	$1.95

Two samples collected by Mr. David Jones in the Hoodoo tunnel last October and assayed by different persons gave $43.70 and $4 per ton respectively.

Messrs. Merrill and Sandt collected two samples of ore from Union Hill last September which gave $8.56 and $4.70 per ton, respectively, or a mean of $6.63.

No sample of ore collected in the field can give as just a view of the real value of an ore-property as the results of a mill-run; and I am therefore much indebted to the courtesy of Captain

Boyd and the officers of the company in permitting me to use the following data obtained from a mill-run undertaken last October. This mill-run, as he explains, was of Union Hill ore, but was made during unusually cold weather, which froze the water on the plates in spite of all precautions. Despite these unfavorable conditions, he obtained $117 in gold from 40 tons of ore, which gives a value of $2.92 per ton. (He estimates that the unfavorable conditions of the run resulted in a loss of nearly two-thirds of the gold or $5, which would make the value of the ore treated $8 per ton, exclusive of the value of the concentrates, which he thinks will represent 1 to 80 in the porphyry ore of Union Hill, and 1 to 5 in the ore of the Hoodoo tunnel.)

The available quantity of the Union Hill ore depends upon the proportion which the porphyry of the hill bears to the country-rock above water-level. What we know about the hill is that its outer shell is composed of porphyry, and a part of its inner nucleus of the quartzites and shales, through which the former has forced its way. Various views have been held in regard to the geological epoch and the manner in which these outflows took place.

Numerous evidences of flow along the bedding and between the strata, as well as through rifts made by the upheaval of the measures, may be found in this part of the Black Hills. A similar rock in Wales has been thought by eminent geologists to be the result of volcanic outburst through several separated vents followed by a shower of ashes, which latter were later compacted into felsitic beds, which in course of consolidation become porphyritic. It is quite probable that there have been many such vents in this region, though several of them probably united in the production of a single sheet of molten rock.

Various observations tend to support the view that the porphyry of Union Hill strikes N.W. and S.E., and may have been derived either from an outflow through a fracture in that direction (since this does not correspond with the strike of the Archean schists) or from a series of vents, produced between the planes of the schist at different horizons, which united their outflows into one sheet.

The broken and fragmental character of the rock in parts of the Hoodoo main and branch tunnels would indicate the close

proximity of the cause of disturbance, even if the actual intersection of both these drifts by porphyry were not observed. On the other hand, the continuance of porphyry (as I am reliably informed) throughout the 300 feet of the shaft, indicates either that the shaft has accidentally been located in a vent, or that the whole covering of porphyry is prodigiously thick. The former seems the more probable supposition, because, at a short distance from the shaft, a large mass of quartzite may be seen embedded in the igneous rock, and apparently at a considerable distance from any quartzite in place, as if it had been carried bodily upward in the igneous flow.

The specific gravity of an average specimen of the porphyry was found to be 2.755. A cubic foot of this rock would thus weigh 171.64 pounds, and a cubic yard about $2\frac{1}{3}$ tons. The distance on the Union Hill property from the line of Strawberry gulch and its small eastern branch to the mouth of the Hoodoo tunnel is about 2418 feet. Assuming a width of 1050 feet, which would include a large part of the company's property, and 256 feet, as the surveyor's estimate of the vertical depth of the mouth of the Hoodoo tunnel below the shaft-house, we have 619,008,000 cubic feet. Taking half of this amount, or 309,504,000 cubic feet, as the cubic contents of the hill, and half of these contents, or 154,752,000 cubic feet, as consisting of porphyry, there would then be 26,617,344,000 pounds, or 13,308,672 tons of porphyry above water-level. Assuming the average value of \$1.95 per ton which resulted from the assays of ore which I selected, this would represent \$25,951,910. Assuming the value actually obtained by Captain Boyd's mill-run of 40 tons (and without allowing for the loss which he believes to have taken place) or \$2.92 per ton, the contents of the Union Hill would be valued at \$38,861,322.

I add a table, which, from a professional point of view, must be regarded as a curiosity. It represents assays of twelve samples of carefully averaged ore made by three assayers of high reputation. There is no doubt whatever that the material of each of these triplicate assays was in a metallurgical sense the same.

For the purpose of getting a better insight into the true character of these porphyries, several specimens collected at different parts of Union hill were subjected to examinations under the

Union Hill Ores, near Galena, S. D.

Mark.	Assayers.	Gold.		Silver.		Total Value of Gold and Silver.
		Ounces per Ton of 2000 Pounds.	Value, $20.67 per Ounce.	Ounces per Ton of 2000 Pounds.	Value, 60 Cents per Ounce.	
1	A. B. C.	0.100 0.300 0.230	$2.067 6.200 4.754	.... 2.35	.... $1.41	$2.067 6.200 6.15
2	A. B. C.	0.08 0.15 0.08	$1.6536 3.10 1.6536	.... 1.08	.... $0.64	$1.65 3.10 2.30
3	A. B. C.	0.10 0.20 0.13	$2.067 4.130 2.68	.... 0.89	.... $0.53	$2.067 4.130 3.21
4	A. B. C.	0.06 0.25 0.14	$1.2402 5.1700 2.8900	.... 0.46	.... $0.276	$1.24 5.17 3.15
5	A. B. C.	0.08 0.125 0.08	$1.6536 2.58 1.6536	.... 0.90	.... $0.54	$1.6536 2.58 2.1936
6	A. B. C.	0.06 0.125 0.14	$1.2402 2.58 2.89	.... 0.31	.... $0.486	$1.2402 2.58 3.37
7	A. B. C.	0.04 0.125 0.04	$0.8263 2.58 0.80	.... 0.36	.... $0.216	$0.8268 2.58 1.01
8	A. B. O.	.... 0.125 0.03	.... $2.58 0.6201	.... 0.31	.... $0.1860	.... $2.58 0.8061
9	A. B. C.	0.02 0.125 0.05	$0.4134 2.58 1.035	.... 0.25	.... $0.150	$0.4134 2.58 1.18
10	A. B. C.	.... 0.1 0.08	.... $2.06 1.65	.... 0.20	.... $0.12	.... $2.06 1.77
11	A. B. C.	0.04 0.075 0.04	$0.8268 1.55 0.8268	.... 0.40	.... $0.24	$0.8268 1.55 1.06
12	A. B. C.	0.040 0.200 0.07	$0.8268 4.13 1.4469	.... 0.37	.... $0.224	$0.8268 4.13 1.67

Union Hill Ores, near Galena, S. D.—Continued.

	Assayers.	Gold. Value, $20.67 per Ounce.	Silver. Value, 60 Cents per Ounce.	Total Value of Gold and Silver.
Average.	A.	$1.0676	....	$1.0676
	B.	3.27	....	3.27
	C.	1.9083	$0.4181	2.3233

microscope as coarse powder and as thin slides in polarized light. Three specimens of this coarse powder were also kindly examined by Dr. Edgar F. Smith of the University of Pennsylvania, in his laboratory, for their percentage of alkalies and of silica.

Microscopical Examination of the Concentrates From the Porphyry of Union Hill.

It was an interesting question, in connection with this free-milling rock, in what state the gold occurred, whether free or attached to the pyrite or other minerals. The condition of the silver, which the assays proved to exist in eight or ten times larger quantity than the gold, was also very interesting.

An experienced assayer reported the existence of "concentrates with the appearance of pyrites largely mixed with hard particles of hematite, which was probably derived from the decomposition of the pyrites. A few colors of gold were visible which have a good yellow color. . . . In all of the samples the relation of gold and silver fluctuates with some regularity." . . . .

(L).—An examination of a quantity of concentrates under a magnification of about 100 diameters revealed gold in the free state and of a good yellow color (showing it unalloyed with silver), but in almost every case attached to a pyrite fragment.

In several instances the association was as a lining to a little cavity, or in a crack of the pyrite, differing from it in color and luster and apparently uncontaminated by combination with any other substance.

Of the other metallic minerals present in the concentrates, pyrite and hematite and some limonite (named in the order of

their quantity) formed perhaps 90 per cent. Besides these there were numerous non-metallic mineral fragments, both of original and of secondary character, which were very interesting and unexpected. It should be remembered that the greater number of the specimens of porphyry from which the concentrates were obtained came from points on or near surfaces which had been exposed to moisture and air for a considerable time, and therefore cannot be supposed to represent with certainty the character of the interior mass of the porphyry.

Following roughly the order of their frequency, the minerals were orthoclase (both pegmatolite and sanidine), pyroxene, and a yellow silicate (?), the nature of which was not determined with certainty, but which is not suspected of being either rare or important. It may be serpentine.

A second examination of this concentrate follows.

A comparatively large amount of the porphyry was concentrated by panning, and examined under magnifying powers of 60 and 120 diameters, and proved to contain pyrite, quartz, rounded milky grains of feldspar, also reddish translucent grains with occasional circular groups on a surface exhibiting high refracting power, and resembling pegmatolite. Occasionally these two appearances are exhibited by the same grain. Translucent and generally rounded grains showing pale bluish or bluish green color and opalescence in transmitted light were observed; also yellowish, barely translucent grains, and a minute mass of the finest hair-gold interwoven into little knobs, and spongy in appearance.

There were also fragments of a dark bluish black mineral with metallic lustre and perfect cleavage on at least one plane (galenite) and argentite(?), diopside, beryl (one fragment), and cassiterite(? ?).

Dr. Amos P. Brown, of the University of Pennsylvania, gives as his description of this powder (1) magnetite, (2) pyrrhotite, (3) pyrite, (4) chalcopyrite, (5) beryl, (6) serpentine(?—the yellow material alluded to above), (7) cassiterite(? ?) (8) quartz in small amount.

(9. V. 21).—Another specimen was concentrated, and gave the writer pyrite, quartz, pegmatolite, yellowish translucent silicate, native gold, and galenite.

Dr. Brown says of this: "It seems to have the same con-

stituents as (L), but with a large percentage of the magnetic portion, which is mainly pyrrhotite, it would seem." He adds: "As I have no data as to the method of separation of their concentrates, I do not know anything of the specific gravity, and can hence form but a poor guess of the constituents. The dark minerals are not in crystals, so the color and lustre only can be used in determination."

A mass of this same powder which had not been concentrated was given to Dr. Edgar F. Smith, from whom I have the following partial determination:

	Per cent.
SiO_2,	63.53
Al_2O_3 and Fe_2O_3,	22.89
K_2O and Na_2O,	7.35
CaO,	2.80
MgO,	not determined
Undetermined,	3.63
	100.00

The rock is therefore a rhyolite with numerous mineral inclusions, including native gold and combined silver, some of which are, in all probability, of secondary origin, and a few of which may have been transported from other places, inasmuch as all the specimens were taken at no great distance from the surface, and the rock was very generally broken and weathered.

An analysis of this rock was made by Mr. V. Lenher in the John Harrison laboratory of chemistry of the University of Pennsylvania. It proved to be composed of:

	Per cent.
SiO_2,	61.79
Al_2O_3,	17.79
Fe_2O_3,	4.01
CaO,	0.80
MgO,	0.23
K_2O,	4.78
Na_2O,	7.56
Loss on ignition,	3.46
	100.42

This rock resembles in most of the constituents, except the silica and alkalies, a trachyte from Ischia near Naples; but in these latter percentages is nearer to an acmite-trachyte from the Crazy mountains, Montana; both cited by Prof. Kemp.

(1. V. 9).—The examination of this rock in coarse powder gave much the same results as that of the last, except that the

grains, though smaller, were less translucent, and no free gold was observed.

Dr. Brown describes it as containing "(1) magnetite, (2) pyrrhotite, (3) pyrite, (4) diopside (? small amount), (5) quartz and flint. The same dark mineral as in (L) may be (6) cassiterite. (7) Some globular and botryoidal grains closely resemble some forms of cassiterite (or uraninite). There is also a little red opal. Possibly (7) may be limonite or psilomelane, but it is rather black." An analysis of this rock unconcentrated, made by Mr. George William Sargent, in the Harrison chemical laboratory of the University of Pennsylvania, yielded the following results:

	Per cent.
SiO_2,	51.93
Al_2O_3 and Fe_2O_3	31.35
Na_2O,	2.89
K_2O,	6.275
CaO,	0.75
MgO,	0.51
Loss from ignition,	7.26
Total,	100.965

The silica in the specimen is very low, and the alumina and iron sesqui-oxide are very high; yet its position with reference to other more normal specimens leaves no doubt that it is part of the same outflow, modified, no doubt, by weathering.

(E).—This porphyry was obtained from a shallow pit about 900 feet E. of S. of the shaft-house on Union hill, and but a short distance above the main Hoodoo tunnel.

It yielded to the examination of its concentrated powder very much the same results as those above. Quartz and feldspar predominated, and the pyrite was smaller in amount. The quantity of this concentrate was less than the others, though made from an equal quantity of powder. A small fragment of hematite was observed.

Dr. Brown says of it: "Much like (10 V. 22), a large part of the magnetic part seems to be pyrrhotite. Quartz, barite(?), not much pyrite; much black mineral, which looks like rutile or cassiterite."*

* A considerable quantity of this powder was examined for me by Dr. S. P. Sadtler for the presence of tin, with negative results. The existence of cassiterite in this rock must therefore be considered as yet unproven.

The unconcentrated powder of this rock was subjected to a partial analysis under the direction of Dr. Smith, with the following results:

	Per cent.
SiO_2,	66.41
Al_2O_3 and Fe_2O_3,	18.63
CaO,	2.50
Undetermined,	12.46
	100.00

A specimen of the unground rock from this pit was cut and mounted in thin slides for examination by the polarizing microscope.

Under 60 and 120 diameters it proved to consist of a fine granular and hyaline matrix, including a considerable amount of quartz and secondary quartz, in which were imbedded large crystals of some sanidine and pegmatolite. A small amount of mica was also suspected.

In another specimen the sanidine showed considerable corrosion of the edges, and the matrix was of a texture suggesting the presence of silica deposited from solution.

This rock is also a rhyolite, less rich, or perhaps entirely destitute of valuable metallic constituents.

Dr. Brown describes this section thus: "Sanidine in porphyritic crystals, some micro-pegmatitic. Grains of primary quartz and much secondary quartz. This rock had apparently a glassy matrix originally. I do not find muscovite."

In a later note he says: "It is a rhyolite without doubt. I should say it had originally a rather glassy base, but this had become devitrified. It is not apparently a very acid rhyolite, however."

An analysis by Mr. V. Lenher in the John Harrison laboratory of chemistry of the University of Pennsylvania demonstrated:

	Per cent.
SiO_2,	67.10
Al_2O_3.	13.95
Fe_2O_3,	2.72
CaO,	1.54
MgO,	0.59
K_2O,	8.31
Na_2O,	2.43
Loss on ignition,	3.85
	100.49

From its silica, alumina, iron sesqui-oxide, lime and magnesia, this rock resembles one from Flagstaff, Colo.; and in the alkalies a rhyolite from Silver Cliff, Colo., of which analyses are published in the *Handbook of Rocks*.

(10 V. 22).—The appearance under the microscope of the concentrated powder resembles very much that of (9. V. 21), but it contained less pyrite, and no gold was observed.

Dr. Brown's description is as follows: "(1) Magnetite, (2) pyrrhotite, (3) quartz, (4) pyrite, (5) same material as (7) in (1. V. 9), (6) also some of the dark mineral of (L. 7), and yellow of (L. 6), perhaps serpentine. Much quartz, and a larger proportion of pyrrhotite than in the others."

An unconcentrated specimen of this rock was analyzed in the laboratory of the University of Pennsylvania by Mr. George William Sargent, and gave the following results:

	Per cent.
SiO_2,	58.71
Al_2O_3 and Fe_2O_3,	25.65
Na_2O,	3.61
K_2O,	6.69
MgO,	trace.
CaO,	0.29
MnO,	0.73
Loss from ignition,	4.20
Total,	99.88

The silica is still rather low for a rhyolite, which, nevertheless, we must suppose this to have been in its original state.

A specimen of a coarse-grained rock (*a*) obtained from a point near the Union hill shaft on the surface of the hill, when cut into thin slides and examined under the microscope, exhibited a fine-grained matrix, in which rested short, thick slabs of labradorite and large prisms with pyramidal terminations of much disintegrated augite. Besides these, are some crystals of biotite, also small grains of some undetermined silicates and a little secondary quartz. The peculiar fragmentary condition of the pyroxene is striking. It is as if in pseudomorphs, or what appear to be such, though the original form may have been pyroxene.

Much of the granular matrix, associated with the usual accessory minerals accompanying augite or labradorite, is made up of small augite fragments.

This rock seems to be an augite-andesite.

Dr. Brown says of the sections of this rock: "It contains plagioclase, a little sanidine, augite (light-colored), and in a^2 (one of the slides) a little brown hornblende. Very little if any secondary quartz, augite-andesite."

He adds in a subsequent note: "I think this could be safely called a pyroxene-andesite or augite-andesite, although I am of the opinion that some of the pyroxene may have been rhombic. 'Pyroxene-andesite' would be safe."

The Coletta Group.

The Coletta group of mines lies nearly due east of the Black Prince, 1⅓ miles down the valley of the Bear Butte creek. The openings are situated on the top of a steep hill which separates Spring run from Bear Butte creek, and at an average of 300 feet above the beds of the streams. The rock is a quartzite, reported by Capt. Boyd to be here 175 feet thick and overlying the Archean schists, which are nearly vertical. The dip is accordingly slight, about 5°—E. by S., and the ore conforms to this dip, but occurs in a peculiar form, called by Capt. Boyd "corrugations" or "corrugates." From whatever cause, there have been deposited on the upper surface of the quartzite uneven lenticular masses of ore like sausages strung together by slender strings, and dipping longitudinally towards the east. They lie approximately in the same plane at intervals of 30 to 40 feet, parallel with each other, and are intersected by other similar masses at right angles, which increase both the richness and quantity of the ore at their junction.

The cause of this strange phenomenon has been thought to be furrows or troughs made in the surface of the quartzite in which the metalliferous solutions deposited their contents; but the origin of the depressions, and especially of these gridiron-like forms, is not clear. The length to which they continue is not known, the exploitation being terminated in most instances by the contour of the hill.

Measurements of these corrugations show that they are broad and shallow lenticular masses, from 5 to 12 feet wide and from 8 inches to 3 feet thick. Where these lens-shaped masses are united end to end, or at the parts analogous to the connecting-string of the sausages, the rock becomes sandy, and free

gold is found. The mineral matter consists mainly of carbonates of lead containing 50 cents to $12 per ton in silver and 0.2 ounce to 1½ ounces of gold to the ton, and varying between 1 and 40 per cent. of lead. These masses are said to increase in value with depth, which is natural from the manner of their deposit; the heavier and richer metals and their compounds having drifted to the lower planes.

They are all more or less ferruginous, and siderite and magnetite are reported to have been found in them.

The ore exposed is a carbonate of lead containing nodules of cerussite.

Tunnel No. 1, overlooking the valley and the hamlet called Virginia City, was opened on the nose of the hill by Mr. Harris in 1891, in a small shaft or pit sunk by an earlier prospector.

The first pipe, encountered about 4 feet from the tunnel-mouth and drifted on, was 1 foot wide, and increased shortly to 4 feet. The tunnel runs about S. by E., and the drift about E. The greatest thickness of these corrugations was 4 feet, and their greatest width 20 feet. Here the dip of the rock was 5°—E. by S. in a decomposed quartzite. About 150 feet from the mouth of the drift it turns and is run on the small pipe. There are other horizons in the quartzite where the lenticular and gridiron-structure occurs, and pipes of ore connect them.

A number of these tunnels are opened along the northern and eastern face of the hill at not very different levels.

On the eastern face of the hill, in opening No. 5, the plane of the pipes has a strike of about S. 35° W., and the pipes themselves dip about 15°—E. 35° S.

Samples from all the tunnels, Nos. 1 to 5, were taken and averaged, the product being indicated by the letter J below.

A nodule of bright red color was selected from No. 5 and assayed. Vanadinite was found in parts of the face, and especially in small crevices. Specimens were taken from opening No. 4 for examination. At the mouth of No. 5 a pipe 18 inches thick, of yellow color, and containing heavy lead carbonates, was observed. A short distance into the tunnel a flat lenticular mass or pipe, 10 feet wide and of unknown length, runs into the hill at an angle of about 15°—N. 35° W. Some 30 feet south is another twin pipe or corrugation connected with it. This last has a breadth of about 4 feet where observed.

About 100 feet S.W. from No. 5 is another opening, No. 6, into another pipe. Little was found outside these openings as dump, which is indirect testimony favorable to the character of the material excavated.

At 100 feet E. of opening No. 6, and 25 feet lower, a large cavern or stope has been excavated under the lower edge of the quartzite, where a quantity of kaolin appears, and a considerable quantity of ore. The horizon is thought by Capt. Boyd to be the lower edge of the Potsdam, and it is not unlikely that it marks at least the lower edge of a lower Potsdam quartzite. A banded quartzite called "ribbon-quartz" runs through the Archean schists at many localities in this country, which is said to be usually gold-bearing.

At the Lynn, or No. 7, cut, 250 feet from the mouth and at the heading, a series of pipes was found with carbonates of lead averaging from 170 to 500 ounces of silver. This ore was sacked. (About 30 sacks make a ton.) Four tons or more have been taken from this hole. Specimens taken from both sides of this drift were averaged and sampled, and the resultant specimen, labeled L, under which its assay will be seen below. (Vanadinite was also found here.)

The mouth of the Lynn, or No. 7, tunnel is about 300 feet above water-level, and the extreme summit of the hill (which lies about S.E. of tunnel No. 1, and a little north of west of the Lynn tunnel) is about 50 feet above it, but Capt. Boyd estimates the average cover of the mines at about 20 feet.

In general, it may be remarked that in tunnel No. 1 and the openings nearest to it, the pipes or corrugations are in rotten disintegrated rock; but to the southeastward the quartzite in which the pipes are found becomes harder and firmer.

About 300 feet S. 25° E. of this Lynn, or No. 7, tunnel, is another trial-shaft which showed some ore. At a depth of about 8 feet, at the bottom of the shaft a pipe is found striking N. 25° W. and S. 25° E., but the ore is under such light cover that a great deal of it has been disseminated among the clays.

According to Mr. Lynn, the surface indications of a pipe are a red soil and float-ore.

The nearest Archean schists underlying this quartzite which were observed, dipped S. 35° E.—85°.

The assays of the specimens taken from the Coletta workings here follow:

Assays from Coletta Workings.

Mark.	Description.	Dollars per ton. Gold.	Silver.	Lead. p. c.	Dollars, gold, silver and lead per ton. (Lead at 3.25 c. per lb.)
J	Tunnels 1 to 5, . .	7.4412	1.008	5.6	12.0892
Ja	Bright vermilion nodule in No. 5, . .	29.3514	10.068	——	39.4194
K	Tunnel No. 5, . . .	0.4134	0.096	11.17	7.7694
L	Lynn or No. 7 tunnel, .	2.067	27.408	3.67	31.845

The lack of continuity in the ore-sheet caused by the breaks in the spaces between the gridiron of ore-bodies does not prevent a reliable estimate of the amount of ore from being made, for these corrugations persist with remarkable regularity. It was not easy to make a test of the amount of free-milling gold which occurs at the points where the ore-bodies pinch out, but it is likely to prove a large addition to the value of the ore here given. The lead is a valuable associate, and facilitates greatly the treatment in the smelter. With improved means of transportation to the Galena plant, which has already been projected, a large, steady and profitable output may be confidently relied on.

In the upper part of Galena, near the angle of Bear Butte creek referred to, the Archean schists dip S. 30° E.—50°. The exposures show the rock in the hill to be compact, and in places curved and foliated. At this place a contact with porphyry is not far off; in fact nature seems to have arranged the greatest possible number of contacts in this entire region, and to have prepared each contact with its quota of ores. The realization of this fact will explain the great prevalence of the word "contact," which one hears constantly.

At the tunnel in the Cora mine, previously referred to, the opening is at the bottom of a middle quartzite dipping about 5°—S.E. At the upper tunnel, at the junction of the Archean schists with this quartzite, is plainly shown the former group, a pinkish mica schist dipping E. 20° S.—38°. (This low dip is doubtless due to the sagging of the laminæ exposed on the upper side of the hill). The quartzite lying immediately upon it dips E. 10° S.—18°.

Mr. Mall, an old and experienced miner, states that in general, the quartzite of this region is thought by the experienced miners to dip E. at a low angle, and the schists S.E.

It has been mentioned that on top of the Cora hill is a capping of porphyry destitute of valuable mineral contents. The cleavage-planes of this rock seem to conform to bed-planes of the quartzite and dip 60°—E. 10° S.

At another opening on a contact of quartzite with the overlying shales, a quantity of cherty-looking red oxide of iron is observable. Lamellar oxides of iron with conchoidal fracture and smooth surfaces follow this upper contact. It would be important to know whether this merges into pyrite deeper and further into the mine, where it is less exposed to the weather.

The Cora mine produced galenite, silver and gold.

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